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Identification and Assessment of Human Error in CNG Stations with SHERPA Technique

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ABSTRACT

Human error is known to be the primary and principal causes of accidents in high risk industries such as oil and gas industries. This study has been mainly conducted because of the importance and sensitive nature of these industries in identifying and assessing human error in CNG stations.

This descriptive-sectional study was performed using SHERPA technique in order to govern and assess human errors in CNG stations of Khoy County - Iran. Initially, desirable information was collected using task observation and interviews with safety responsibilities, authorities of units and operators. Subsequently, through HTA (Hierarchical Task Analysis) the critical tasks were defined. Finally, human errors in each critical tasks were recognized and assessed using SHERPA technique (systematically human error reduction and prediction method).

Analysis of SHERPA questionnaires exhibited that, the total number of identified human errors in CNG job positions were equivalent to 113 errors, thereby highest and lowest percentages of errors were action error (51.33%) and communication error (3.54%), respectively. Based on the results, (63.7 %) of the identified errors risks were reported intolerable.

In order to prevent and decrease the identified errors, and their consequences, reducing the rate of these errors is essential. In addition, appropriate control measures in the form of hardware changes in equipment design, periodic training courses and updating work instructions, and stress management as well as avoiding fatigue are to be prioritized towards corrective actions.

Moreover, according to the results, the action errors with highest rate of errors should be considered for priority control measures.

KEYWORDS
Human error, Risk assessment, CNG, HTA and SHERPA

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Introduction

Human error is considered as the most important cause of occupational and non-occupational accidents. To reduce errors which result in adverse consequences, it is necessary to identify, forecast and analyze the considered factors. Moreover, appropriate control strategies are proposed to reduce the errors which lead to adverse consequences (Mohammadian et al., 2012). Researches demonstrated that, the major causes of accidents in oil and gas industry was reactor explosion which largely happens due to the weakness in designing of reactors. Indeed, it has to be noted that the human error might influence on the process performance during diverse stages (Omidvari and Gharmaroudi, 2015). In recent decades, numerous incidents like pesticide Factory explosion in Bhopal (India), Chernobyl disaster, Three Mile Island, Challenger Space Shuttle disaster, and Texas refinery and airline accidents had histrionic consequences (Dekker, 2014). Studies revealed that, between 20 to 90 percent of system failure has occurred due to the human performance, and more than 90 percent of all the accidents in industries has happened due to human error (Brauer, 2016). Studies conducted by the Pennsylvania Industrial Organization concluded that, out of 80,000 incidents investigated, unsafe conditions and unsafe acts were related meticulously in about 98% cases. Essentially, designs must limit human error opportunities and reducing human error that could lead to accidents (Stanton et al, 2013). To estimate the value of human error for a special measure, related tasks are divided and these individual tasks are assessed properly to accomplish human reliability (Akyuz and Celik, 2015). Investigation of accidents demonstrated human error to be a key factor in accidents occurring in critical situations, which is not significant in industries because longer time is taken for retrieval and recovery (Meshkati and et al., 2016). Analysis of fundamental causes of some events such as release of flammable and explosive chemicals in the environment is one of the most indispensable steps to improve safety in existing or under-processing design units (Eckle and Burgherr, 2013). There exist numerous methods to identify and evaluate the errors in different jobs, among them, SHERPA technique is of the most common technique. Human error can be investigated in terms of type of error, possible outcomes and control/preventive solutions.

SHERPA provide necessary requirements to identify shifts and operator psychological recovery, and reconstruction of acceptable and valid values (Di Pasquale et al., 2015).

In SHERPA technique, HTA (Hierarchical Task Analysis) together with Errors Classification (action error, retrieval error, checking error, selection error and communication error) are employed. In this method, it is presumed that every steps are analyzed, and every error types are listed and defined. Subsequently, consequences of errors, and the probability and criticality of errors is ultimately determined, thereby control solution is proposed. There are eight stages in SHERPA analysis. In the first stage, using HTA analysts a general division of task into subtasks is done which displays the performance potential (Hughes et al., 2015). Analysis of job, in definition, means study and analysis of all stages and activities to achieve the main goal of an activity (Ghafari et al., 2016). SHERPA tasks-classification is summarized in the following five categories: 1-Action (for example, pressing a button), 2-Retrieval (for example, reading from a screen), 3-Checking (for example, task process study), 4-Selecting one option over another and 5-Information and communication (for example, speaking with individuals) (Bilgard and Osvalder, 2014). To examine SHERPA, identification of systems and human beings is essential, and investigations for process improvements are to be done which aims in classifying the errors that occur (Boring, 2015). The foremost risk of CNG distribution stations is the threat towards people. Also, according to the conducted researches, recommendations such as minimum safe distance from the rupture of the central reactor, extreme pressure, fire or the release of toxins were done (Parvini and Kordrostami, 2014). When natural gas is distributed throughout the community with 200 BAR pressure equivalent to 3000 PSI, awareness towards people should be raised with a similar sensitivity, and areas of risk and disaster must be reduced, and the consequences of any involvement in natural gas vehicle has to be noted. Therefore, more external factors and human errors can be reduced and eliminated, risks can be easily controlled, and injuries can be avoided. CNG equipments with precise tools such as sensors, as well as pressure and temperature gauges, safety valves, pressure vessels and storage tanks need to be inspected occasionally at the adjusted intervals, and in accordance with the standards for avoiding accidents (Sarabi et al., 2009).

Accurate identification of human factors in urban CNG fueling stations, as well as the impact of materials used and safety control measuring are altogether mandatory for integrated management in stations. Ceasing preventive measures, and then human unsafe events causes could prevent industrial accidents and different features of flaws. Therefore, improvement in defense level, and enhancement of quality are considered as human controlling and preventive factors (Cia et al., 2012).

Inflammatory nature of natural gas, intimacy of CNG stations to residential areas and comparable incidents at these stations in recent years in different parts of the world, confirm the requirement of present research. This study is the primary research to assess the type and extent of human error in CNG stations in Iran. Towards this objective, CNG stations of Khoy County-Iran have been examined using SHERPA technique, and representation of control measures apposite to prevention, elimination or reduction human error, and limiting the consequences such as deaths and injuries caused by accidents has been carried out.

Materials and Methods

This study was a descriptive cross-sectional investigation which intended to identify and assess human errors related to CNG stations, which has been conducted among the population of managers and staff members. SHERPA technique was applied to identify and assess the potential human error in these positions. To perform SHERPA technique, eight necessary steps were executed. First, Examination of administrative activities using HTA technique, and then task classification which are to be considered at each stage in order classify the errors:

Measure (Action): Pressing a button or turning the switch.

Retrieve: Receiving information from the monitor or instructions and regulations.

Checking Out : Conducting and administration of an investigation process.

Selection: Choose a different approach with respect to the command of higher responsibility.

Exchange of information (Communication): Conversations with other departments.

Subsequently, classification of task step guides the analyst to investigate the activity error using downstream error classification. Then, consequence analysis, recovery analysis and ultimately ordinal probability analysis are done with low, medium and high group classifications. If the results are considered to be critical (lead to unacceptable injuries) it should be paid attention. For implementing the steps, MIL-STD- 882B standard was employed.

The aforementioned standard was proposed for the first time, in 1984 to be employed in US military industry, where the risks were classified into four classes like catastrophic, critical, border and slight. Although this standard was primarily employed to evaluate military systems but is now employed for a wide range of industries (Stanton and et al., 2005).

Error Reduction strategies has been offered in the final stage in the form of suggestion for work system change which could prevent errors. Basically, these strategies are classified in four categories (Haji Hoseini, 2011) as mentioned below:

Equipments (Redesign or development of existing equipment).

Training (Change in training process).

Instructions (Presenting new instructions or reforming the old ones).

Organization (Making changes in organization policy).

This current study is conducted based on SHERPA technique with the following 5 steps:

Step 1: Job analysis by HTA method - To ensure this, after the acquaintance of operators with work method, and the intention of this study and details of their task in CNG stations, through interviews and observations, and data acquisition, ultimately main tasks were outlined in HTA format.

Step 2: Identify the probable errors in CNG stations - In this stage, identification of errors were done based on SHERPA technique.

Step 3: In this step, recognized errors were codified and based on instructions of technique implementation, their type was determined (Table 1).

Table 1: Types of identified errors based on error

Percent	Error Number	Error Description	Error Code	Error Type
7/08	8	Action is done too early or too late	A1	Action Error
2/65	3	Not accomplishing the task in due time	A2	
7/08	8	Wrongly accomplished task	A3	
1/77	2	A task accomplished lesser or greater than expectation	A4	
1/77	2	Change action occurs	A5	
-	-	Accurate action is done on wrong alternative	A6	
2/65	3	Wrong action is done on accurate alternative	A7	
15/04	17	Action accomplishment is forgotten	A8	
9/73	11	Incomplete action	A9	
3/54	4	Wrong action is done on wrong alternative	A10	
9/73	11	Revision is forgotten	C1	Control Error
12/39	14	Revision is done incompletely	C2	
-	-	Accurate revision is done on wrong alternative	C3	
5/31	6	Wrong revision is done on accurate alternative	C4	
3/54	4	Revision is done in wrong time	C5	
-	-	Wrong revision is done on wrong alternative	C6	
2/65	3	Required information is inaccessible	R1	Retrieval Error
1/77	2	Information is wrongly presented	R2	
-	-	Incomplete retrieval of information	R3	
0/88	1	Information exchange does not take place	I1	Communication Error
1/77	2	Information exchange is wrong	I2	
0/88	1	Information Exchange is incomplete	I3	
8/00	9	Selection is eliminated	S1	Selection error
1/77	2	Selection is done wrongly	S2	
100.00	113			Total number

Step 4: Error risks assessment - In this portion of the study, identified errors have been assessed based on risk probability and consequences severity.

Step 5: Analysis of Errors - Develop control measures, revise and reformation of assessment results. In this step, identified errors were analyzed and thereby appropriate control measures was developed, required revisions and reforms was done.

Findings

In this study, eleven CNG stations in Khoy County were investigated. Nine tasks and thirty two subtasks were determined for positions staff as entailed in Table 2.

Major causes of identified errors include non-accomplishment of job duties, job assignment later than the due date, incomplete task accomplishment and forgetting to inspect. Therefore, the probability of every errors in an emergency situation can be very critical. SHERPA and HTA analysis sample sheets are shown in Tables 2 and 3.

Figure 1. Error Numbers Based on Type

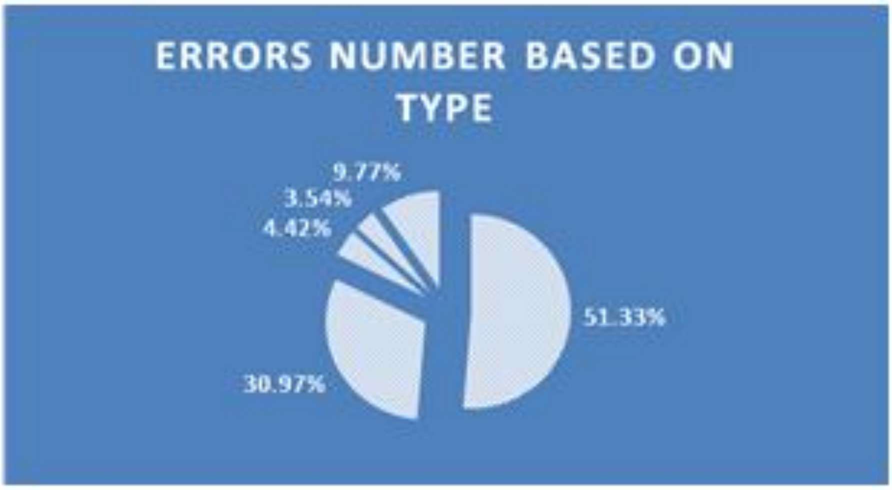


Table 2: A sample of HTA analysis (incidents control in CNG stations)

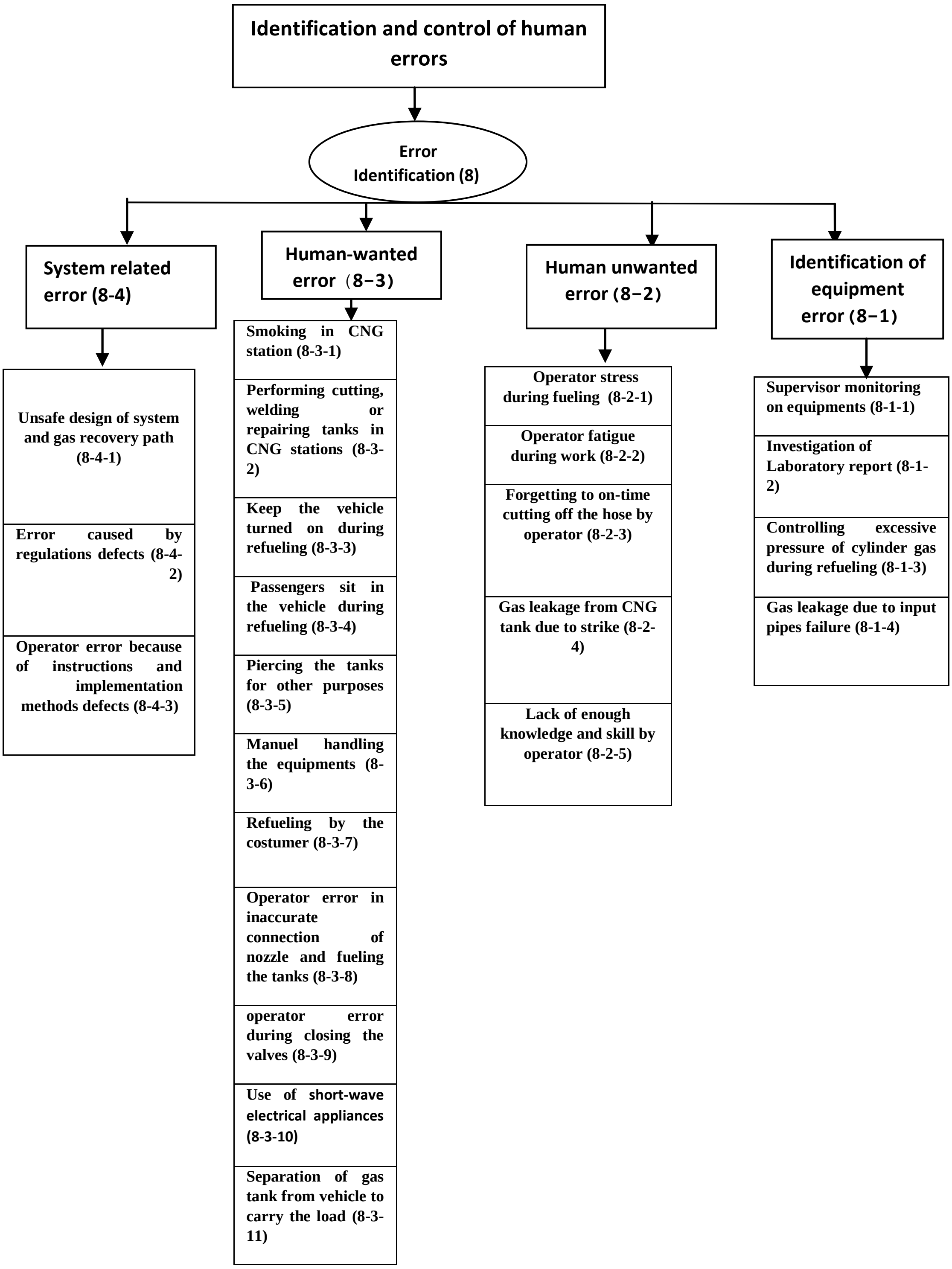


Table 3: A sample of SHERPA worksheet applied to errors identification

Task row #	Duty	Error Type	Error Description	Error Consequences	Risk Level	Control Measures	redicted Risk
8-3-6	Manual handling of equipments	A5	Change action is done	Change in primary shape of the equipments may lead to incidents	1B	Periodic and sudden inspections	1C
8-3-7	Refueling by costumer	S2	Wrong selection is done	Client distraction during nozzle connection which leads to incident	2A	Director and super-operator inspection	2C
8-3-8	Operator error in wrong connection of nozzle during tank fueling	A3	Considered action is done wrongly	Nozzles stick and high pressure gas return, and dealing with gas inlet that leads to dislocation of outlet spencer hose and explosion	1A	Operator training as well as preparation of regulations and organizationa l policy for correct connection	1D
8-3-9	Operator error during valves closing	A7	Wrong action is done on right alternative	Not discharging the gas of tank or pipe to prevent from pressure excessive boost	2B	Operator training as well as preparation of regulations and organizationa l policy for valves	2E
8-3-10	Use of short-wave electrical appliance	A2	Considered action is done wrongly	Clash of strong electro-magnetic radiation to metal objects which lead to sparks due to flammable clouds	2A	Director and super-operator inspection and installation of warning signs	2E
8-3-11	Separation of tank from vehicle to carry the load	A3	Considered action is done wrongly	Gas leakage and pieces failure cause to incidents probability increase	1A	Technical inspection of vehicles	1B

Table 4: Frequency and percentage of different type of errors

Action Error	Checking Error	Retrieval Error	Communication Error	Selection Error	Total
Number (percent)	Number (percent)	Number (percent)	Number (percent)	Number (percent)	Number (percent)
58(%51/33)	35(%30/97)	5(%4.42)	4(%3/54)	11(%9/77)	113(%100)

As displayed in Table 4, 51/33 %, 30/97 %, 4/42 %, 3/54% and 9/77% of the identified errors were related to action error, checking error, retrieval error, communication error and selection error, respectively. Action error, in this study was ranked as the highest level of SHERPA classification, which is in different levels of forgetting, incomplete accomplishment, or soon or late task accomplishment. In CNG stations, annual inspections of sector will be conducted to monitor the performance of equipment, where inspectors control the performance of the control room operators. 33% of the total strategies were related to monitoring and inspection, which has shown the highest percentage among every strategy (Tables 5 and 6).

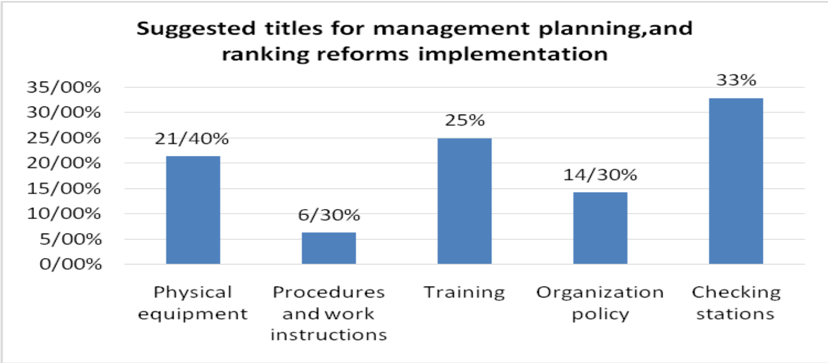
Table 5: Proposed titles for management planning, as well as ranking reforms implementation

Percent of total value	The number of repetition	Proposed titles	Row
21/4	27	Physical Equipment and facilities	1
6/3	8	Procedures and work instructions	2
25	32	Training	3
14/3	18	Organization Policy	4
33	41	Checking stations	5
100	126	Total	6

Table 6: Frequency and percentage of proposed titles for management planning, and ranking reforms implementation

Physical equipment	Procedures and work instructions	Training	Organization policy	Checking stations	Total
Number (percent)	Number (percent	Number (percent)	Number (percent)	Number (percent)	Number (percent)
27(21/4%)	8(6/3%)	32(25%)	18(14/3%)	44(33%)	126(100%)

Figure 2. Suggested Titles



Of the total amount of studied risk, unacceptable risk and undesirable risk were reported as 63.7% and 28.50. %, Respectively.

After implementing the control measures in the studied station, the level of unacceptable risk would be reduced to 4.90%, and the undesirable risk will decreased 8.90% and reached to the amount of 19.60%, and the level of accepted risk without any revisions by carrying out control measures will be reached to 67.65% in the future. Moreover, 7.90% of the available risk is ranked as acceptable risks (safe) (Tables 7 and 8).

Table 7: Frequency and percentage of error risks before control measures

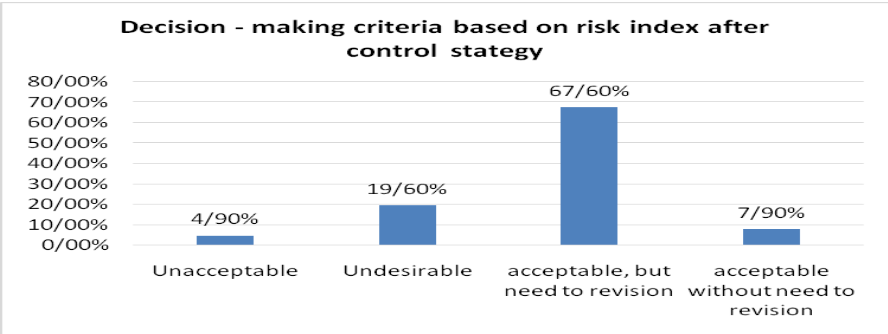
Unacceptable	Undesirable	Acceptable, but need revision	Acceptable without need in revision	Total
Number (percent)	Number (percent)	Number (percent)	Number (percent)	Number (percent)
65(63/7%)	29(28/5%)	5(4/9%)	3(2/9%)	102(100%)

Figure 3. Decision Making Criteria before Control Strategy

Table 8: Frequency and percentage of error risks after control measures

Unacceptable	Undesirable	Acceptable, but need revision	Acceptable without need in revision	Total
Number (percent)	Number (percent)	Number (percent)	Number (percent)	Number (percent)
5(4/9%)	20(19/6%)	69(67/6%)	8(7/9%)	102(100%)

Figure 4. Decision Making Criteria after Control Strategy



Analysis of SHERPA worksheets displayed that, the total number of identified human errors in CNG stations tasks includes 113 errors. Of these, the largest and the lowest percentage of errors are allocated to action risk and communication risk with 51/33% and 3/54%, respectively. 63/7% of identified errors is unacceptable, and the highest percentage of proposed titles for the management planning, and ranking of reforms implementation related to the checking of the stands is 33%.

Results and Discussions

Studies have shown that defects in structure and other problems caused by accidents at CNG Stations, are mainly associated with human error. Safety of Used Material has greatly reduced incidents, and human unsafe behavior has increased by events. Every Activities related to CNG refueling stations can be controlled by humans. And during production process, even in very good conditions and advanced technology equipments in CNG fueling stations, if the managers disregard human presence and management, accidents may occur. Paying attention to human error of CNG fueling stations is an important management measure in risk control at CNG stations (Cai et al., 2012). The foremost objective of this research is to identify and assess the human errors of CNG stations using SHERPA technique, thereby determining error risk and ultimate risk level after corrective measures. Study on the effects of HTA and SHERPA methods, (Lane et al., 2006) concluded that the two mentioned techniques together, has the ability to forecast and notice human errors, particularly in sensitive industries such as power plants, pharmaceutical, petrochemical and nuclear industries which is reliable on the methods used in this study. In another study carried out by Stanton and colleagues regarding human errors prediction, they demonstrated that the analysis of human errors might be more acceptable, whenever the analysis has been done by several analysts. Chief part of identified errors were of action errors (51/33%) that is consistent with the studies conducted in the fire investigation in iron ore mine (55%) by Karimi et al., (2015) and professional dental clinic in Tehran (60%) by Shams Ghareneh et al., (2015) in Banbury unit of a rubber industry (38/63%) by Shirali et al., (2015). It has to be noted that, the type of workplace of these aforementioned researches were not similar to the current study. Checking error in second rank (30/97%) and communication errors in the last place has shown the lowest percentage of errors. Results displayed that, among the errors detected, unacceptable risk (63/7%) is reduced to 4.9% by control measures. This research was consistent with the study conducted with the same method in post-control room of 400 kV (54/2%) by Jafari et al., (2012) and also the control room of the Isfahan Petrochemical Industries (71.25%) by Ghasemi et al., (2011). According to results achieved from the current study, the highest identified error was Action error type, thereby several suggestions are proposed in order to reduce these type of errors using corrective measures including training, compilation and updating task instructions, applying experienced operators, stress and fatigue management, precise and periodic inspection, and improvement of management system. These measures could affect strangely on reduction of unacceptable risk. On the other hand, results displayed that the studied technique is applied in petrochemical, medical, oil and gas industries for identifying and assessing human errors.

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